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POLARIZATION CONVERSION ELEMENT, POLARIZATION ILLUMINATOR, DISPLAY USING THE SAME ILLUMINATOR, AND [PROJECTION TYPE DISPLAY] PROJECTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a polarizing conversion device and a polarizing illumination device for generating, from incident light beams as randomly polarized beams, illuminating beams that have a more uniform light intensity distribution in an illumination region than that of the incident beams and are polarized in almost the same direction. Furthermore, the present invention relates to a display apparatus and a projection display apparatus using these devices.

2. Description of Related Art

A polarizing illumination device capable of efficiently generating the same type of polarized light beams is ideal as an illuminating device for use in a display apparatus, such as a liquid crystal apparatus, which employs a panel for modulating polarized light beams. Accordingly, an illuminating optical system has been proposed that converts random polarized light beams emitted from a light source into the same type of polarized light beams and illuminates a liquid crystal apparatus with the light beams so that a bright display is achieved. Japanese Unexamined Patent Publication No. 7-294906 discloses an image display apparatus equipped with such an illuminating optical system.

The principal part of the illuminating optical system disclosed in Japanese Unexamined Patent Publication No. 7-294906 will be briefly described with reference to FIG. 15. This optical system mainly comprises a lens plate 910, a plurality of polarizing beam splitters 920, a plurality of reflecting prisms 930, and a plurality of $\lambda/2$ phase plates 940. Incident beams as randomly polarized beams are separated into two types of polarized beams (P polarized beams and S polarized beams) through the polarizing beam splitters 920 which are respectively provided with polarizing separation planes 331 and the reflecting prisms 930 which are respectively provided with reflecting planes 332. After the separation, the polarization direction of polarized beams of one of the types is matched with that of polarized beams of the other type by using the $\lambda/2$ phase plates 940, thereby obtaining polarized beams of the same type and illuminating a liquid crystal device 950 with the light beams. In general, since a space for forming two types of polarized beams therein is needed in the polarized beam separation process, the optical system is inevitably widened. Accordingly, this optical system reduces the diameter of the beams, which are incident on the respective polarizing beam splitters 920, to less than about half the diameter of small lenses 911 formed in the lens plate 910 by means of the small lenses 911, and places the reflecting prisms (reflecting planes) 930 in the spaces produced by the reduction of the diameter of the beams, whereby the same type of polarized beams are obtained without widening the optical system.

The optical system disclosed in Japanese Unexamined Patent Publication No. 7-294906 has, however, the following problems.

In reducing the diameter of the beam by the lens, generally, the minimum beam diameter is almost directly and exclusively determined by the refractive power of the lens and parallelism of the light beam incident on the lens. That is, in order to reduce the beam diameter to less than half the lens diameter as in the optical system disclosed in

Japanese Unexamined Patent Publication No. 7-294906, it is necessary to use a lens having an extremely high refractive power (in other words, a lens having an extremely small F-number) and a light source capable of emitting a light beam having extremely high parallelism. However, a real light source has a limited emission area. Therefore, parallelism of the light beam emitted from the light source is not always good.

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On the other hand, the polarizing separation ability of the polarizing separation plane formed in the polarizing beam splitter is highly dependent on the incident angle of light. In other words, when the light that is incident on the polarizing separation plane has a large angular component, the polarizing separation plane cannot exhibit an ideal polarizing separation ability, the S polarized beam mixes into the P polarized beam transmitting through the polarizing separation plane, and the P polarized beam mixes into the S polarized beam reflected from the polarizing separation plane. Consequently, it is impossible to excessively increase the refractive power of the small lens used for reducing the diameter of the beam.

For the above reasons, it is difficult to sufficiently reduce the diameter of the light beam that is incident on the polarizing beam splitter, and, in actuality, a relatively large amount of light also directly enters the reflecting prism adjoining the polarizing beam splitter. The light that is directly incident on the reflecting prism is reflected by the reflecting plane, enters the adjoining polarizing beam splitter, and is separated into two types of polarized beams by the polarizing separation plane in the same manner as the light beam that is directly incident on the polarizing beam splitter. The light beam that is incident on the polarizing beam splitter through the reflecting prism and the light beam that is directly incident on the polarizing beam splitter are different by 90° in the incident with respect to the polarizing beam splitter. As a consequence of the existence of the light beam directly incident on the reflecting prism, the S polarized beam directly incident on the reflecting prism and separated through the polarizing beam splitter mixes into the P polarized beam that transmits through the polarizing beam splitter without changing its direction of travel. Similarly, the S polarized beam mixes into the P polarized beam that directly enters the polarizing beam splitter and is emitted through the reflecting prism and the $\lambda/2$ phase plate. Since the S polarized beam mixed into the P polarized beam because of the existence of the light beam directly incident on the reflecting prism is quite unnecessary for the liquid crystal device, it is absorbed by a polarizing plate and generates heat, which is the main factor that increases the temperature of the polarizing plate.

Thus, in the process in which the conventional optical system disclosed in Japanese Unexamined Patent Publication No. 7-294906 converts random light beams emitted from the light source into polarized beams of the same type, a relatively large number of polarized beams of another type inevitably mix. As a result, the polarized beams, which are unnecessary for display and are polarized in a different direction, are required to be absorbed by the polarizing plate in order to obtain an extremely bright display image. In addition, a large cooling device is essential to restrict the increase in temperature of the polarizing plate caused by the absorption of the polarizerd beams.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to solve the above problems by substantially restricting the mixing of

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tion means for illumination light for illuminating the liquid crystal devices.

The liquid crystal devices 414, 415, and 416 used in this embodiment are of the reflection-type. They modulate respective colored lights, and provide the colored lights with corresponding external display information. At the same time, they respectively change the polarization directions of the light beams emitted from the liquid crystal devices, and almost reverse the direction of travel of the light beams. Therefore, the light beams respectively reflected from the liquid crystal devices are partially brought to a P polarized state according to display information, and then emitted. The modulated light beams emitted from the liquid crystal devices 414, 415, and 416 (mainly P polarized beams) enter the crossed dichroic prism 450 again, are synthesized into one optical image, and enter the adjoining polarizing beam splitter 480 again. That is, the crossed dichroic prism 450 acts as the colored light synthesizing means for the modulated light beams emitted from the liquid crystal devices.

Since the light beams modulated by the liquid crystal devices 414, 415, and 416 of the light beams that are incident on the polarizing beam splitter 480 are P polarized beams, they transmit through the polarizing separation plane 481 of the polarizing beam splitter 480 unchanged, and form an image on a screen 470 through the projection lens 460.

The projection display apparatus 4 having such a structure also employs liquid crystal devices that each modulate one type of polarized beam, similarly to the above described projection display apparatus 3. Therefore, when a conventional illumination device for using randomly polarized beams as illumination light is employed, light beams separated by the polarizing beam splitter 480 and directed to the reflection-type liquid crystal devices are reduced to approximately half the number of the randomly polarized beams, the light use efficiency is low and a bright projection image is difficult to obtain. In the projection display apparatus 4 of this embodiment, however, such a problem is substantially improved.

That is, the projection display apparatus 4 of this embodiment can efficiently generate substantially the same type of polarized beams, that are polarized in the same direction, by using the polarizing illumination device 1 of the present invention instead of the conventional illumination device, and therefore, almost all light beams that are incident on the polarizing beam splitter 480 are directed as illumination light beams to the reflection-type liquid crystal devices 414, 415, and 416 located at three positions. As a result, it is possible to obtain a bright projection image that is uniform in brightness and color.

Particularly, in the polarizing illumination device 1 used as an illumination device, since the shading plate 370 is placed inside the second optical element 300, other polarized beams that are unnecessary for display on the liquid crystal apparatus hardly mix into the illumination light emitted from the polarizing illumination device 1. Therefore, it is possible to obtain high-quality illumination light beams polarized in the same direction, and to thereby succeed in obtaining a high-quality bright projection image.

Moreover, the second optical element 300 in the polarizing illumination device 1 spatially separates two types of polarized beams in the lateral direction (the X direction). Therefore, the polarizing illumination device 1 does not waste the light and is convenient for illuminating a liquid crystal device shaped like a laterally extended rectangle.

As described in connection with the above described first embodiment, the widening of light beams emitted from the polarizing separation unit array 320 is restricted although the polarizing illumination device 1 of this embodiment incorporates polarizing conversion optical elements therein. This means that minimal light enters the liquid crystal device at a large angle in illuminating the liquid crystal device. Accordingly, it is possible to achieve a bright projection image without using a projection lens system having a small F-number and an extremely large aperture, and to thereby achieve a compact projection display apparatus.

Condenser lenses 417 may be respectively interposed between the crossed dichroic prism 450 and the liquid crystal devices 414, 415, and 416 located at three positions in the projection display apparatus 4 of this embodiment. FIG. 14 shows a schematic structure of an optical system in that situation. Since such placement of these condenser lenses allows illumination light beams from the polarizing illumination device 1 to be directed to the liquid crystal devices while restricting the widening of the light beams, it is possible to further improve the efficiency in illuminating the liquid crystal devices, and the incident efficiency in making light beams reflected by the liquid crystal devices enter the projection lens 460. From the viewpoint of reduction of light losses at the lens interfaces, it is preferable to place each condenser lens integrally with the liquid crystal device as shown in FIG. 14, or with the crossed dichroic prism.

Although S polarized beams are used as illumination light in the projection display apparatus 4 of this embodiment, P polarized beams may be used as illumination light. In this case, the polarizing illumination device 1 and the crossed dichroic prism 450 are placed opposed to each other through the polarizing beam splitter 480.

Furthermore, though the crossed dichroic prism is used as the colored light separation means and the colored light synthesizing means in this embodiment, the projection display apparatus may comprise two dichroic mirrors instead. Of course, it is also possible in that case to incorporate the polarizing illumination device of this embodiment, and to form a high-quality bright projection image having a high light use efficiency, similarly to this embodiment.

As described above, according to the present invention, it is possible to achieve a polarizing conversion device and a polarizing illumination device capable of generating with high efficiency only the same type of polarized beams that have a more uniform light intensity distribution in a illumination region than incident light beams, and, at the same, that are polarized in the same direction. Furthermore, it is possible to easily achieve a display apparatus and a projection display apparatus capable of displaying a high-quality bright image through the use of the polarizing conversion device and the polarizing illumination device of the present invention.

CM We claim:

1. A polarizing conversion device, comprising:

a polarizing separation element having a light incident side, a light emergent side, a polarizing separation plane that separates P and S polarized beams by transmitting one of the P and S polarized beams therethrough toward the light emergent side of the polarizing separation element and reflecting the other of the P and S polarized beams, and a reflecting plane disposed substantially parallel with said polarizing separation plane that reflects the other of the P and S polarized beams reflected by said polarizing separation plane toward the light emergent side of the polarizing separation element;

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